

## STRATEGIES FOR SONIC INTERACTION DESIGN: FROM CONTEXT TO BASIC DESIGN

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### ABSTRACT

We advocate a new approach to the design of interactive and sonically augmented artifacts. It is aimed at enriching the context within which design takes place, while integrating the level of structured exploration that has been instrumental to formalizing design processes for nearly a century. The proposed process combines the systematic approach of basic design with exploratory studies within an existing everyday setting. The approach is particularly salient for auditory display in products, due to the relative lack of design examples and methods that exist for those working in this area to draw upon. We describe a study undertaken in domestic kitchen, a setting that has long been recognized as ripe with expressive, sonic interactions. The results of this contextual research have been used for the design of sonically-augmented lamps. We analyze the relevant results, and describe plans for integrating assessment methods.

### 1. INTRODUCTION

The design of auditory displays for interaction with everyday objects is of increasing relevance to product designers, and has already exerted a palpable influence within a research community that is emerging around the subject of sonic interaction design [1], [2]. Economies of scale have contributed to an increased array of products with intrinsic sensing and actuating capabilities that can be used to shape their interactive appearances and behaviors. Likewise, techniques for the interactive synthesis of sound, including everyday sounds, have advanced so as to provide new ways for auditory displays in products to be seamlessly integrated into activities and to sonically mesh with diverse sonic environments. The result is an increase in opportunity for the design of interactive sound in everyday products. This development is significant for research, because new challenges are certain to emerge that confront both the design and engineering of auditory displays. One area of already urgent need concerns the development of new creative strategies, as many existing design methods have not been developed with interactive auditory displays in mind.

The generation of new interactive sonic products requires methods and tools suitable to the design task. There is a need for more knowledge about how to integrate creative practices with contextual influences (users, environments, or activities) that are seen as key elements of situated design practices. This gap between creative practice and situated practice is particularly acute in sonic interaction design, where far fewer design case studies can be found. A primary aim of the work we report on is to take steps toward bridging this methodological gap.



Figure 1: *Everyday objects afford simple, yet causally and sonically interesting interactions: Pushing the top part of the juicer leads to the deformation of an orange, the activation of a motor, the rotation of a surface, the grinding of the fruit's flesh, and the dripping of the juice into the cup.*

We discuss a process for the creation of sonically augmented artifacts that are highly responsive to physical manipulation. It is grounded in the analysis of existing activities within a context of interest that has been identified as source material for creation of basic design studies. The studies concerned are constructed from novel links coupling elementary actions and everyday sounds found within the context of investigation. They result in concepts for new, abstracted sonic artifacts affording simple actions and providing continuous sonic feedback.

As an example, this process has been applied to the design of a set of interactive sonic lamps generated from the observation and analysis of food preparation activities in a kitchen context (Figure 5). The resulting artifacts reflect features drawn from and inspired by this context. They are significant for revealing potentially novel links between action and sound in the physical manipulation of artifacts, toward informing the design of computational artifacts that utilize sound in new ways.

#### 1.1. Basic Design Practices for Sonic Interaction Design

Historically, Basic Design has combined educational practice with the theoretical and methodological foundation of design [3]. It originates in the kindergarden movement and was first taught as a

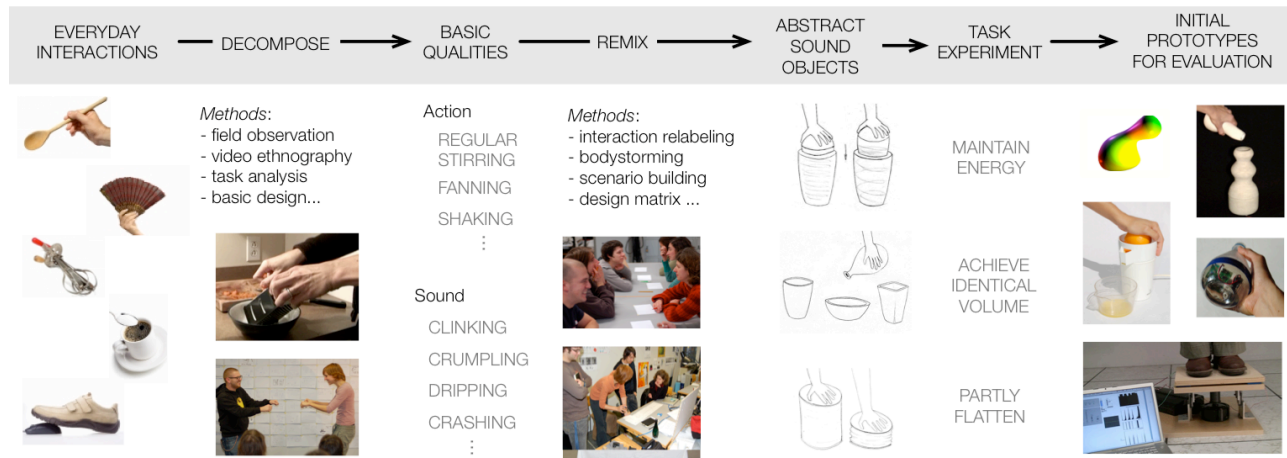


Figure 2: Overview of design process: Although it is represented as a linear sequence, the activities concerned were conducted on an iterated basis, in which stages or sequences were repeated several times.

design practice at Bauhaus School of Art and Architecture, and at the Vkhutemas school in Moscow, during the early part of the last century. The practice was based predominantly on visual experience, and its analysis in terms of simple, abstract properties, such as forms, patterns, or colors.

The Bauhaus explored formal abstraction in relation to human perception, with the aim of uncovering a universal visual language, independent from such cultural limitations as are present in alphabetical writing. In these experiments, researchers were not interested in individual preferences, but in intuitive responses and in the most frequently occurring perceptual relations between abstract properties – graphics, color, texture and so on – influenced by contemporary developments in psychology.

Some Bauhaus members disassociated their aims from the quest of universal language, and began to employ the manipulation of basic elements primarily for generating new design ideas. New artefacts were designed through experimentation with elements of shape, form, color, texture and others, while exploring the perceptual experiences they afford. For example, tactile charts and structures explored sensations of pressure, temperature, and vibration, bringing relational complexity into abstract design (Figure 3). “If the same methodology was used generally in all fields we would have the key to our age seeing everything in relationship,” as Moholy-Nagy put it (Moholy-Nagy [4], p. 96).

### 1.1.1. Basic Sonic Interaction Design

Applied to interaction design, Basic Design allows to study and to experiment with combinations of elements that contribute to an interactive experience with an artifact. As Moholy-Nagy did, we see design affordances as arising from the interplay of artifact’s properties, rather than upon an understanding of these as separate elements. As an extension of these ideas, *basic interaction design* can be thought of as a practice and theory focused on analyzing and designing the relationships between sonic, formal, haptic and behavioural qualities of interactive artefacts.

In the Bauhaus, an abstract element was linked to its dynamic properties: “Line is a the track made by the moving point: that is, its product. It is created by movement...” (Kandinsky, [5], p. 71).

Similarly, everyday sound is created through physical interaction that can be readily described in these terms: the sound of pouring water, the sound of walking, of cutting, typing, and so forth. Relations between potential abstract elements or properties of a design are more complex where interactive sonic artifacts are concerned than they are in the case of purely graphic design.

Basic Design’s methods, such as the reduction, translation and morphological analysis, and its explorations of tactile properties and movement, make it particularly suitable for design of everyday sonic interactions. In what follows we provide a case study for what may be thought of as *basic sonic interaction design*, a practice focused on understanding and designing the relations between sonic, formal and physically interactive, or movement-based properties of sounding artefacts.



Figure 3: Moholy-Nagy’s hand sculptures, basic studies in designing for the hand.

### 1.2. Situated Basic Design: Sound in Context

An emphasis on understanding the situation in which action takes place was first championed in human-computer interaction (HCI) by Lucy Suchmann [6], who was inspired, in part, by developments in educational psychology. She argued against the interpretation of user behavior as a rational planning process, and against the interpretation of actions and tasks as separable from their contexts. The material and social circumstances of an experience should be seen, she argued, as essential to intelligent action, and

interactive artifacts as an opportunity for enhancing situated actions.

Within HCI there has been an increasing exploration of interaction within everyday situations, in part through the adoption of methods having their origin in ethnography [7]. This has been particularly true of research areas such as computer-supported cooperative work and participatory design. Designers applying such methods engage directly in the contextual research process, as part of the overall design cycle, often inventing new context-centred methods in the process (see for example [8]).

Paul Dourish has argued [9] that there are significant gaps in the application of ethnographic methods within HCI, because the goal of the latter is often misunderstood as implications for design, rather than as strategies whereby the investigator may immerse himself or herself in the experience under study. If as Dourish argues, the goal of ethnographic research is to reveal and explain real world experiences rather than narrowly to provide input for new designs, additional methods are required to include contextual findings in the design process. How, then, as designers can we integrate the creative components of our practice with embedded, reflective, analytic, and context-immersed research practices?

Combining these approaches may be of particular benefit in interactive sound design for everyday artifacts. Firstly, because the sonic experience they afford depends upon a match to particular sonic contexts and relations with other elements of the relevant soundscape(s). Secondly, because such artifacts link typically focused, often manual actions on the part of a user to sonic information that, again, derives its meaning from relation to the contexts in which they operate. An electric drill, seen as a sounding artifact, is likewise an agent for the expression through sound of the amplification of its user's act of construction.

#### 1.2.1. Contextual effects in everyday sound perception

Common experience suggests that context has a high significance for the perception of everyday sounds. Screaming at a fairground, for example, is essentially diametrically opposed in meaning to that which occurs in the soundtrack of a horror film. Past research has examined the role of contextual information in the perception of everyday sound events. Ballas and Mullins systematically studied the role of non-linguistic semantic information in the identification of temporally proximal everyday sounds [10]. Others have examined different forms of conceptual priming (eg. labels) in everyday sound perception [11]. Southworth found that the location (for example, an urban site) in which a sound was known to have occurred influenced how it is evaluated [12]. Ozcan and van Egmond found auditory semantic information for product sounds to be fuzzy in general, suggesting that contextual information may play a significant role in disambiguating semantically ambiguous product sound classes, such as various machine sounds [13]. Because of the profound effect that such contextual information can have, we believe that sound designers would be well-served by drawing upon them as an equally important constituent element for the design process.

### 1.3. Abstracting From the Everyday Sonic Experiences

The basic interaction design methodology we propose starts from real world experiences. The pitfall of the basic design approach is that it fails to account for contextual influences on the qualities of the designed object. It is not only the perception of a product's sound that changes relative to the context (say, the enveloping

soundscape), but the object moreover acquires its cultural meaning and patterns of use (i.e. interaction) through this embedding. For this reason, we propose to augment basic product sound design practices with contextual elements. Although most of the basic design exercises developed during the Bauhaus use predefined geometrical shapes and colors, some work during and preceding this period proscribes the analysis and reduction from real world objects to define an abstract element [14]. Similarly, we propose to integrate contextual influences into a formalized design method based on the abstraction of compositional elements for design from studies of selected everyday interactions.

## 2. CASE STUDY: COOKING, SOUND AND ILLUMINATION

Bill Verplank is credited with once having asked the question (paraphrasing): "Why can't I be as expressive with the computer as I can in the kitchen?". The domestic kitchen was adopted as a context rich in meaningful action-sound relationships that might serve as design material for new sonically-augmented artifacts. In this study, this material was oriented toward the creation of interactive table lamps.

### 2.1. Action-Sound Analysis in the Kitchen

The domestic kitchen was selected as a rich context in which to study sound-action relationships, because it is filled with artefacts allowing for complex physical actions and moreover in interaction with these, sound is produced. The kitchen tools that were included in the initial analysis range from simple manual tools, such as knives or spoons, to mechanical tools with moving parts, such as garlic squeezers, and finally to the vast array of electromechanical kitchen appliances, such as toasters, coffee grinders and blenders. The latter possess interfaces separated from their mechanisms, while in the first two groups the operation is more transparent, as the action and its effect are directly linked. Moreover, sound is also generated through chemical and physical processes such as fizzing, burning, boiling, or freezing. Due to the intended emphasis of the study, chemical and electromechanical processes were omitted, as they did not involve performative engagement from the side of the user.



Figure 4: A still video frame from audiovisual documentation of everyday activities.

The investigation was based on the notion of self-reflective exploration, more comparable to abstraction methods from basic design than to ethnographically-derived field study. Interactions were performed in context, recorded and analyzed. In this way it was possible to reduce the pitfalls of analytic observation while making a fast study which helped to define elements relevant for

active sonic experiences. This approach allowed the design researchers to experience directly the importance of everyday sound for action, to critically address problems through examples or reveal new ones, to map meaningful relations between function, task, action and sound as they were experienced, to gain insights into the significance of the kitchen context and to define elements and moments that might be designed for.

### 2.1.1. Exploring kitchen processes

Field work began with the audiovisual documentation of a number common cooking activities performed by the designers themselves. The recordings were acquired with a single video camera and microphone placed near the interaction locus, to capture sonic details. Forty-eight individual audiovisual sequences of kitchen processes were acquired, with recordings ranging in length from approximately twenty seconds to a few minutes.

The relevance of sound was informally explored by removing sonic and visual feedback, accomplished through revisiting the video material with sound muted and repeating the experience or video playback with the eyes closed. This revealed the information missing in observing an action without sound (seeing a person stirring does not provide much information about the density of food stirred) and the support sound provides when visual feedback is not present (pouring sounds provide information about the volume of the vessel).<sup>1</sup>

### 2.1.2. Sound analysis, annotation and description

A formal description of sounds generated by the documented processes was undertaken. Sound descriptions were based on common methods from psychoacoustics, from musical sound, and from ecological everyday sound categorization [15]. Table 1 provides an overview of the notation used. The evaluation was based on a subjective accounting of the phenomena experienced and observed, with an emphasis on direct experience, due to the usual difficulties of ascribing significance to phenomena accompanying interaction purely through observation. Hypotheses were formulated as to the significance of specific sounds elements for performance in the relevant situation. Key points about the relevance of sonic feedback included the notion that sound can affect performance, can help focus the attention to the action, can affect intentionality and that its loudness is in relation to action energy (AE) and duration (AD) as in the case of the sound produced by tilting the pitcher in the coffee making process described below.

### 2.1.3. Action decomposition

Actions that caused the sound were analyzed through an adopted version of task analysis method [16] and a number of action descriptors defined by the authors (see Table 1). Elementary primitive actions were identified as those actions that appeared repeatedly in the studied examples, to which no specific meaning could be assigned when isolated from each other and from the task context. Together these comprised approximately thirty primitives. These were grouped into two categories. Those (about one dozen) which cannot be decomposed into smaller actions but would still be perceived by the performer as single actions were referred to as

<sup>1</sup>For an example, see the Sonic Vessel design process described below. A complete documentation of this study is available at URL <http://actionanalysis.wikispaces.com>

Action - General Parameters	
AD	Duration of action in seconds
AE	Energy exerted during manipulation
Action Descriptors (Examples)	
Elementary	Push, hit, slide, squeeze, grasp, elevate, put down, remove, tilt, turn, spin
Composite	Pulling, moving in circular motion, smoothing, uncoiling, turning, picking up, pouring, ...
Sound - General Labels	
MS	Manipulative sound
AS	Automatic sound
NSf	Incidental or weak feedback for action
RSf	Relevant for action
Sound - Dynamics	
<i>pp, mp, mf, f, ff, ...</i>	
Sound Descriptor Types (selection)	
Psychoacoustic	Loudness, brightness, ...
Physical source	Aerodynamic, liquid, solid, combustion, ...
Material	Elasticity, density, ...
Configuration	Shape, size, structure (resonant cavities, etc), support, weight
Surface contact	Smooth, rough, regular/grated, jagged ...
Spatial qualities	Delay, reverb, echo, damping, perspective, distance, resonance, ...
Soundscape	Location/context, interpretation, semantic interactions, ...
Gestalt / pattern	Rhythm of vibration, iteration of sound event (e.g. bouncing), ...

Table 1: Summary of notation and annotations used for action-sound analysis. For an example, see section 2.1.4.

*basic* action primitives. These included directional movement and pressure (push, hit, slide), embracing pressure (squeeze, grasp), displacing while holding (elevate, put down, remove) and rotation (tilt, turn, spin). *Composed* actions primitives, on the other hand, were taken to be those in which two or more basic action primitives occur together simultaneously. For example, pulling is composed of squeezing and moving in a certain direction, and picking something up is composed of embracing, maintaining constant pressure, so the object doesn't fall, while generating a displacement.

The development of a taxonomy of such design elements, even constrained to the domestic kitchen contexts considered in this work, would exceed the scope of this research. However, we believe that such a taxonomy would be a valuable, if challenging and complex, contribution toward establishing an approach to the design of tangible interactive artifacts. Within the scope of this study, the action and sound examples that were gathered proved useful as source material for basic design exploration and for the creation of abstract sound artifacts.

### 2.1.4. Example: Pouring Water

Audio-visual documentation was acquired of the experience of coffee making with an stove top espresso maker (cafétierra). The coffee making process was analyzed as described above. The analyses of sound and action related to the activity of pouring the water in the cafétierra is as follows (for abbreviations of descriptors see



Table 1).

1. *Action: Grasping and squeezing the handle of the pitcher.* The squeezing continues in all steps of pouring.
  - (a) *Sound: The sounds of squeezing the handle of the pitcher.* Plastic and skin interaction. This sound continues throughout the whole process becoming more or less audible due to other sounds produced. MS.
    - Relevance of sonic feedback (RSf): The sound communicates the firmness of the grip. Slipping or movement of the fingers on the handle can be heard. Can be rather silent.
2. *Action: Elevating the pitcher from the counter.* AE: depends on the size and material of the pitcher and quantity of liquid in it.
  - (a) *Sound: The short impact and friction sounds.* Caused by the contact between the counter and pitcher. MS.
    - RSf: N/A However it provides information about the material of the pitcher and surface on which it has been positioned.
3. *Action: Displacing the pitcher towards the cafetiera.* AE: depends on the size and material of the pitcher and quantity of liquid in it. AD: 2s
  - (a) *Sound: Moving liquid in the pitcher.* The liquid hits the walls of the pitcher. MS.
    - RSf: It communicates the quantity of water in the pitcher. Can lead to the action of refilling of the pitcher.
4. *Action: Tilting the pitcher, while aiming at cafetiera.* AE: Larger than in the previous action, but still depends on the size and material of the pitcher and quantity of water in it. AD: 2-3s
  - (a) *Sound: Water impacting the bottom of the metal cafetiera followed by the sound of splashing: water hitting the water surface.* The sound changes continuously as the volume of the cafetiera is being filled. The sound is louder than that of other actions. If there is not sufficient liquid in the pitcher, the sound of filling will end with the sound of dripping. MS.
    - RSf: The sound provides information of how filled the vessel is. Stovetop cafetiera has a valve in its bottom part which is filled with the water. This valve is a limit to which one can pour the water.
5. *Action: Tilting the pitcher back to vertical position.* AE: Smaller than in the previous action, because less liquid is contained in the pitcher. AD: 2s
  - (a) *Sound: Moving liquid in the pitcher.* The liquid hits the walls of the pitcher. MS.
    - RSf: It communicates how much water is left in the pitcher.

From this analysis, action primitives necessary to accomplish pouring were identified. These were: grasping, squeezing, elevating, displacing and tilting. Several of these actions, and related sounds, happen concurrently. For example, one has to maintain pressure on the pitcher's handle in order to perform any of the subsequent actions. While little to no sound is produced by squeezing, tilting the pitcher to fill in the cafetiera produces a dominant sonic contribution. The sound of the water impacting the vessel that is being filled and the resonant excitation of the metallic volume of cafetiera informs about the level of the liquid poured. A special limit of water in the cafetiera is defined by the height of its valve.

## 2.2. Concepts and Scenarios for Abstract Sound Artifacts

The generation of concepts for abstract objects began with basic design exercises focused on re-mixing sonic and interactive features extracted from context research. One method that can be readily applied in such situations is that of the morphological design matrix [17, 18], which asks the designer to decompose otherwise seemingly non-reducibly complex design problems by organizing the multi-dimensional qualities (sonic, formal, interactive) that characterize them along several axes. In our case, the qualities were those of an interactive sound-based experience. The resulting space is then sampled at individual points, and the resulting set of properties are used to generate a design case.

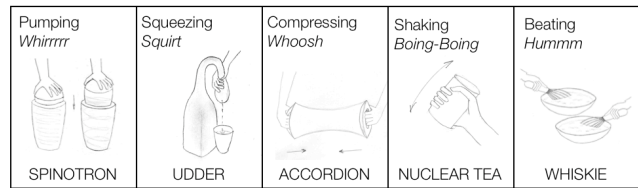


Figure 5: Sketches of abstract sound artifacts.

We applied this method to generate novel design concepts accounting for sonic, formal and interactive qualities of artifacts. A two-dimensional matrix was developed, delineated by one axis corresponding to action primitives identified in the field study and another corresponding to everyday sound processes. By designing the contents of various cells in this matrix, we developed and refined ideas for objects that afford one simple action to which continuous sonic feedback is mapped. Some of the concepts are sketched in figure 5.<sup>2</sup>

## 2.3. Sound Design, Synthesis, and Mapping

There are several important features of the design of synthetic sound in interactive products, including the acquisition of user actions through a set of sensors, the mapping of sensor data to the control parameters of a sound synthesis algorithm, and the nature of the mapping from the physical affordances of the object, as captured through the sensors, to features of the synthesized sound, as encoded in the parameter settings. The situation largely mirrors that of musical interaction design [19]. The study reported on here draws on physically based models of everyday sounds. Such sounds are well motivated by the context research described above,

<sup>2</sup>The complete set of these concepts is available at a dedicated wiki whose URL is: <http://sound-scene-storm.wikispaces.com>

because they directly model the physical processes (rubbing, impacts, pouring) that give rise to sounds in the analyzed cases. As a result, the basic properties of those cases can directly be used as compositional elements of the interactive sound design. This notion of a basic everyday sound palette fits with prior research that has sought to create a hierarchical taxonomy of everyday sound that may be useful to designers [15, 20].

The control mapping task is strongly constrained by the fact that the artifact, as a sound control device, is characterized by a map from physical action affordances (tilting, crushing, rotating) to physical sound-generation processes. Moreover, the nature of this connection may facilitate mental models that associate the action with the resulting sound in a physically causal way, making good use of users' prior experience with the manipulation of everyday objects. Such mappings may be thought of as conceptually direct.

## 2.4. Physical prototyping

The physical production of the artifacts created in this study raise a number of issues that are somewhat beyond the scope of this paper's audience, ranging from industrial design considerations (materials, processes), to electronic sensing (sensor selection, integration, signal conditioning and acquisition), actuation (mechanical design, actuator selection, signal transmission), and real-time software integration (control and sound synthesis models, task implementation, hardware interfacing). One of the examples below gives some indication of how these issues are managed, but the details are omitted from this contribution.

## 2.5. Interactive sonic lamps

We provide examples of prototype artifacts that have resulted from the process of designing abstract sonic artifacts. Those described here are functional studies for interactive lamps. Concepts from which these lamps were developed by composing action primitives and everyday sounds of the analyzed cases described above, together with the functionality of illumination.

### 2.5.1. Case Example: From Cafetiera to Sound Vessel

The Sound Vessel is a lamp inspired by the everyday action of pouring liquids (see also liquid pouring analysis extract above). Its level of light increases with the quantity of matter poured into it. As lighting is linked to the distribution of physical matter, the design concept is a network of the objects that could achieve a more or less distributed quantity of light based on the distribution of matter between the vessels in the space.

Rather than afford interaction directly through manipulation primitives linked to pouring (i.e. grasping, elevating, displacing, tilting), Sound Vessel (Figure 6) employs the intermediate concept of transportable medium to facilitate control of the light. As the lamp is filled with a dry granular material (rice works well), the changes of sound and the level of illumination are linked to the quantity of this material that has entered the vessel.

When one drops granular matter into the Sound Vessel, the sound of pouring liquid accompanies the action. The sound interactively communicates the process of filling and the level of light-liquid poured, similarly to the real experience of pouring water described in the cafetiera example above. In addition, the pouring sound recapitulates the change in level of light, together with the total light, via the water-filled vessel metaphor.



Figure 6: *The Sound Vessel prototype.*

A physical sound synthesis model of liquid sounds is excited by the arrival of material in the vessel, and modulated according to the level of material that has entered it. Sensing is accomplished by an acoustic transducer (piezoelectric contact microphone) coupled to the underside of the interior wall of the vessel, and a force sensor (Interlink FSR model 402) measures the overall weight of the vessel, and consequently the amount of material in it. Sound is reproduced by a small loudspeaker in a cavity beneath the vessel. A small microcontroller board (based on the AVR Atmel Mega 128) acquires the sensor data, and transmits it over a serial link to a computer. The sound synthesis model is implemented as external objects and abstractions within a real time data processing environment (Cycling'74 Max/MSP). The physical artifact was modeled using 3D design software (Rhino3D) and the prototype fabricated with a fused deposition modeling 3D printer. Light is provided by an integrated, high-intensity (3W) full color (RGB) LED module controlled by the microcontroller.

### 2.5.2. Sonic Lamps: Additional Examples

We briefly describe two additional sonic lamp studies. The implementation and production details are broadly similar to the sound vessel, so we abbreviate them here.

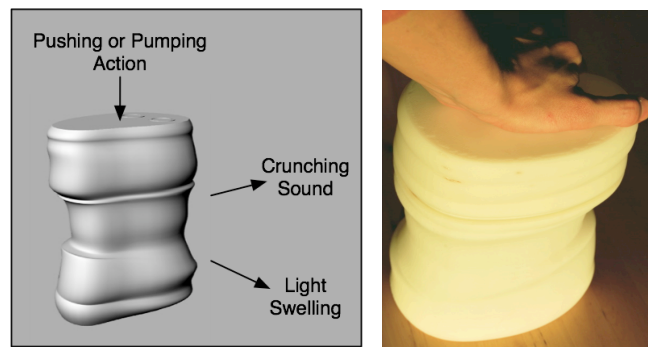


Figure 7: *The Crush prototype and interaction*

*Crush* (Figure 7) represents an object that must be regularly compressed, via a force applied to its top surface while the object rests against a solid (table or similar). The idea was inspired by the action of compressing plastic bottles to recycle them. The accompanying sound is generated by a physical sound synthesis model of the crushing of a can

or the compression of a granular medium, such as gravel. The model has been previously described by Fontana et al. [21, 22]. As the amount of compression that has been applied within a relatively long time window increases, illumination increases. If left alone, the light from the lamp gradually fades.

**Twister** (Figure 8) is a bottle like vessel that affords a continuous twisting motion, tightening over the course of several turns. This action was extracted from the process of closing the two part of a caffetiera. The physical tightening of the top is measured through a mechanism within the artifact. The increase in tightness is expressed through a growing light, and through sound as a resonant squeaking, whose pitch increases and density of squeak-events decreases as the tightness grows.

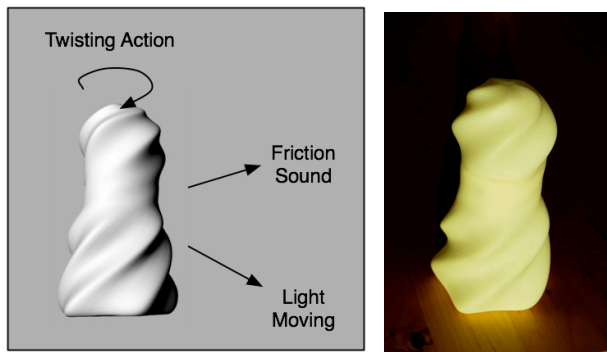


Figure 8: *Twister prototype and interactions*

### 3. REFLECTIONS

In real experiences with everyday objects that produce sound, complex relations between the artifact, action and sound coexist, and link with myriad issues of context of use to give rise to an overall impression on the part of a user. The aim of the process illustrated here is to provide a generative method for working from these existing interconnections toward new design concepts. The top-down nature of this process suggests that the designed artifacts could make positive use of the complex interconnections of meaning that are inherited from the context that is explored.

The starting point of our approach is a context of interaction, broadly considered to be a family of environments, activities, and individuals. The location is selected to provide a rich and ecologically meaningful base for the design activities that follow. Research in context is aimed at discovering concrete connections between elements of the interactions that are revealed therein. From field documentation, specific interactions of interest are identified, at whatever appropriate conceptual and temporal granularity, characterized by a certain set of tasks. The core component is an analysis of actions involved in a process, a description of the sounds involved, and an assessment of the relevance of the sounds to the action performed, as described above.

Parts of this study are similar to formal task analysis, as sometimes applied in human-computer interaction [16]. However, while traditional task analysis is performed from the viewpoint of an idealized detached observer, in the method adopted in this research,

designers, as actors, are engaged in the analysis of their own interactions. In this way, difficulties related to the interpretation of experience solely from the observation of physical action are avoided [23]. Although benefiting from analytic nature of some of the aforementioned HCI methods, user experience is regarded as a unified interactive situation, rather than as logical sequence of tasks to be accomplished [24].

By extending their creative process into real situations, designers shape their creative output in several ways. The latter is influenced by the conclusions that can be drawn from the context research itself, but moreover by the embodied knowledge that they acquire through first-hand experience. Such knowledge cannot be conveyed through design guidelines any more than one can learn to ride a bicycle by reading a book.

In the study described here, we neglected most of the social or cultural dimensions of the activities examined. For example, the studies involved one person in the kitchen context at any time. Others have examined more directly the use of social and cultural influences as design material [8]. Because these factors have an undeniably important effect on the meaning that an activity and situation may hold for a user, they hold significant potential as compositional elements for use in design. Arguably, they should be integrated in the basic design framework demonstrated here. This would provide a greater opportunity for the results to account for the level of complexity of meaning that is created around artifacts in real-world surroundings.

The process leading from basic sonic interaction design concepts to functional artifacts is an interdisciplinary one, combining various areas of design, including auditory display. Also, as described above, context of use affects the ways in which interactive sound is perceived and studied couplings of sound and action are brought back to real life situations through designed objects. On the other hand, basic design provides structural creative methods suitable for unexplored design areas such as that of sonic interaction design. We believe that incorporating basic design thinking in context-based investigation provides useful ways of understanding interactive experiences and shaping the design processes that create them.

### 4. ACKNOWLEDGMENTS

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